



OMI NO₂ column densities over North American urban cities: The effect of satellite footprint resolution

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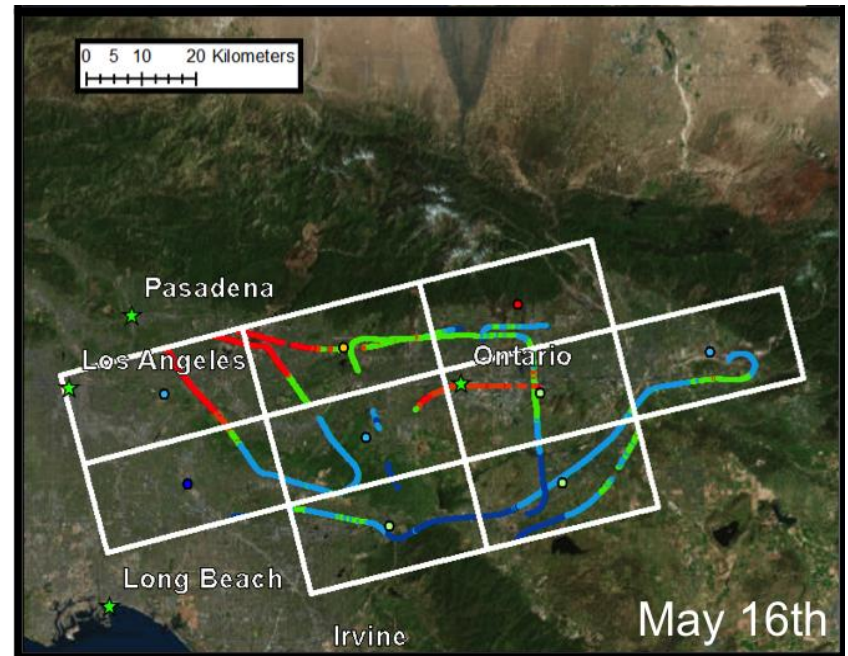
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Motivation

- Comparing satellite NO_2 VCD to regional model is a popular way to evaluate model performance and current emissions inventory
- Urban NO_2 plumes are usually much smaller than satellite footprint pixels (even for OMI), so satellites might cause underestimation over urban cores and overestimation over urban boundary.



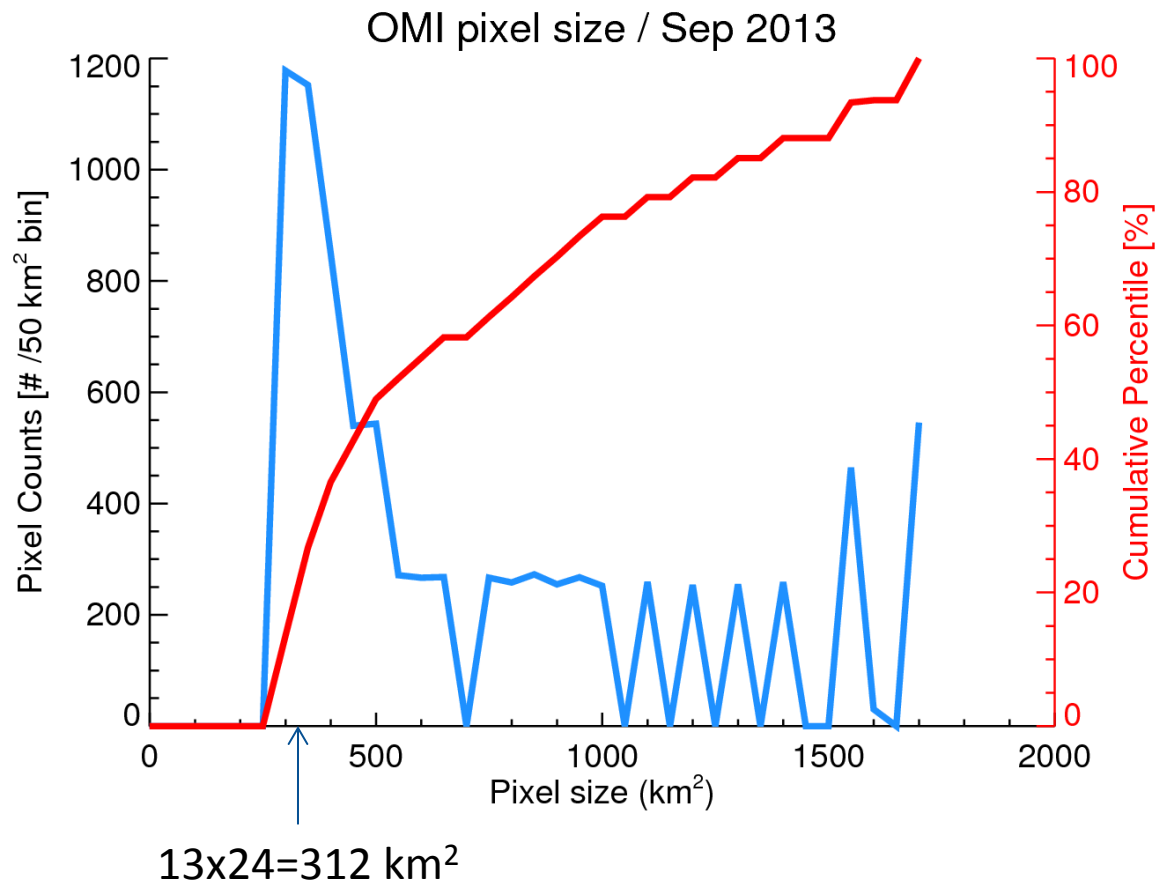
P3 NO_2 VCD with OMI footprint pixels
(CalNex 2010, Judd et al. 2015)



Outline

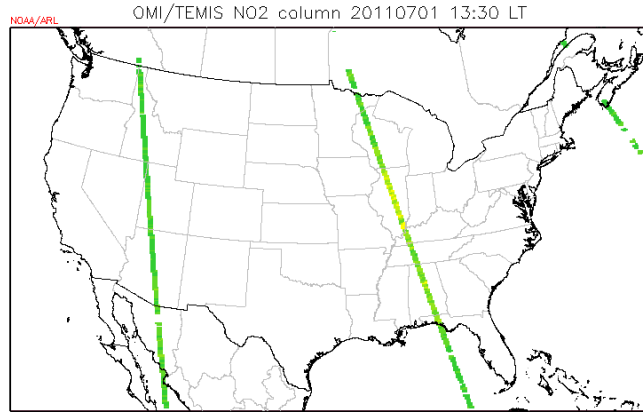
- OMI footprint pixel sizes
- Perfect model experiment with a pseudo-OMI data set
- Downscaling of OMI NO₂ VCD
- Conclusion

OMI footprint pixel size distributions

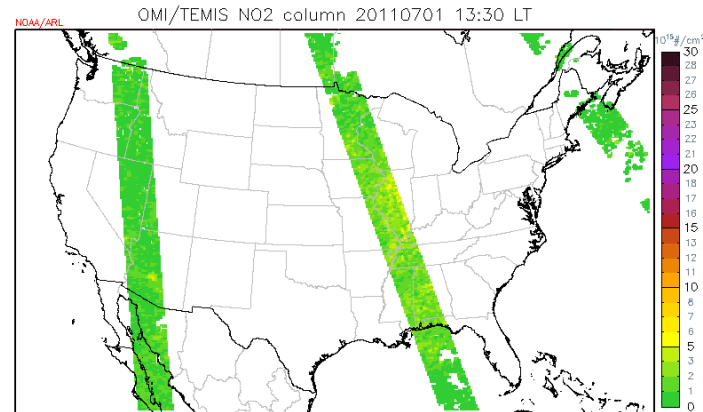


Dilemma of satellite footprint size selection

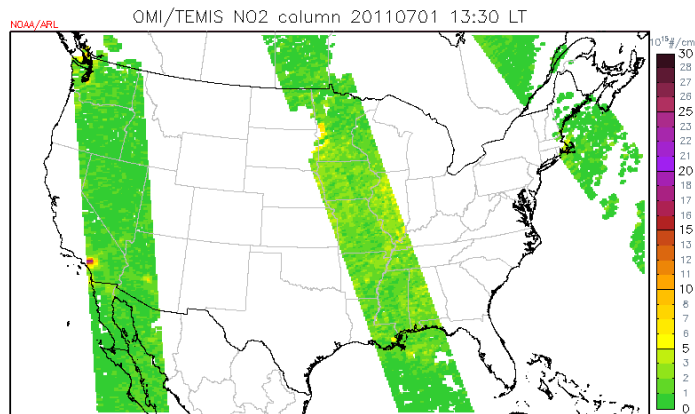
Using fine resolution data means less coverage



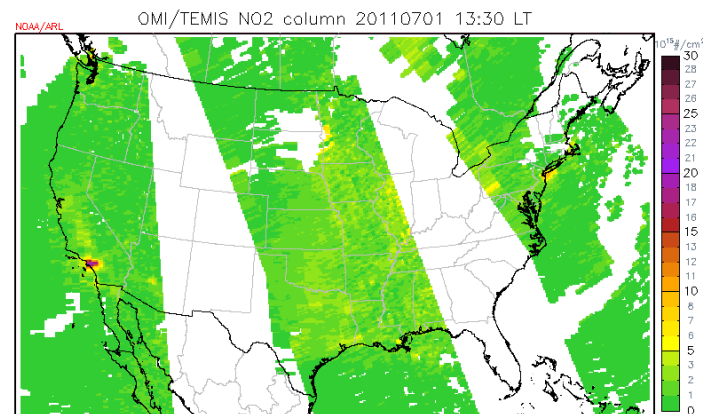
(A) Size < 342 km², Pixel=25%, Coverage= 1.4 %



(B) Size < 450 km², Pixel=50%, Coverage= 11.5 %



(C) Size < 721 km², Pixel=75%, Coverage= 24.0 %



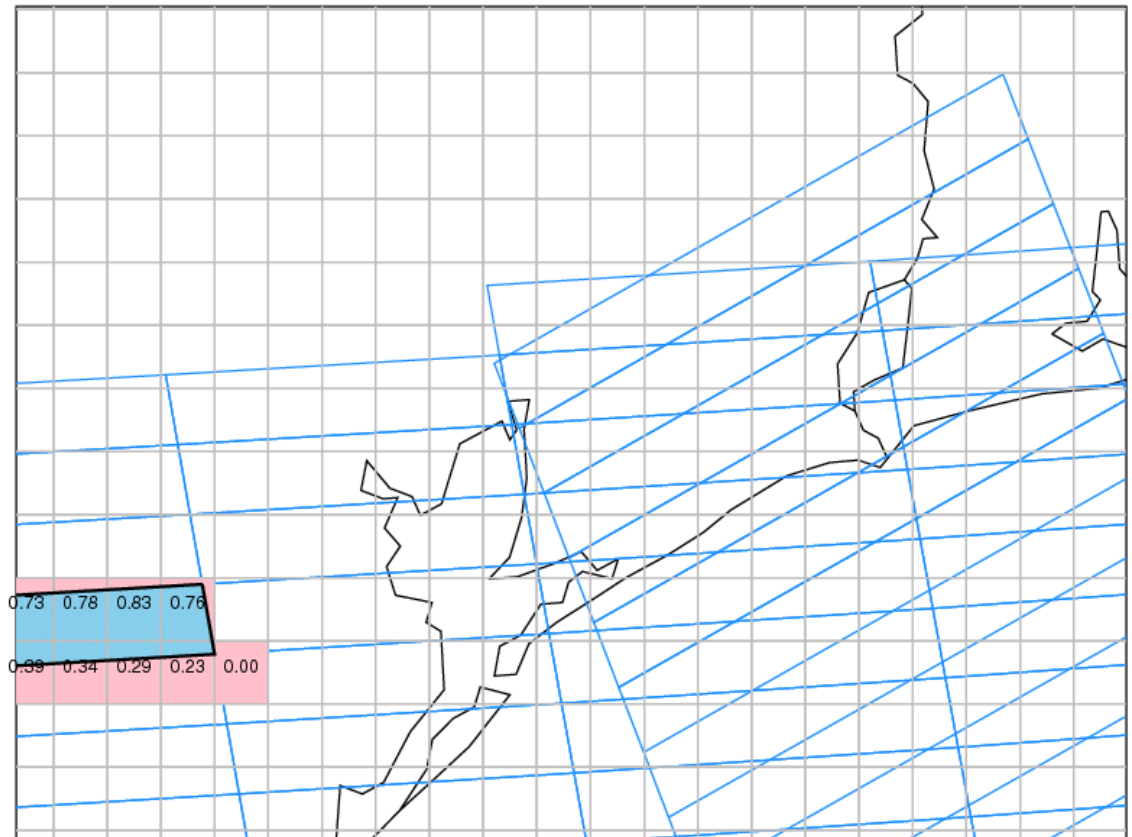
(D) Size < 1732 km², Pixel=100%, Coverage= 58.8 %

Pseudo-OMI data using model: A perfect model experiment

Assuming 12-km CMAQ model is true, a pseudo-OMI set is built.

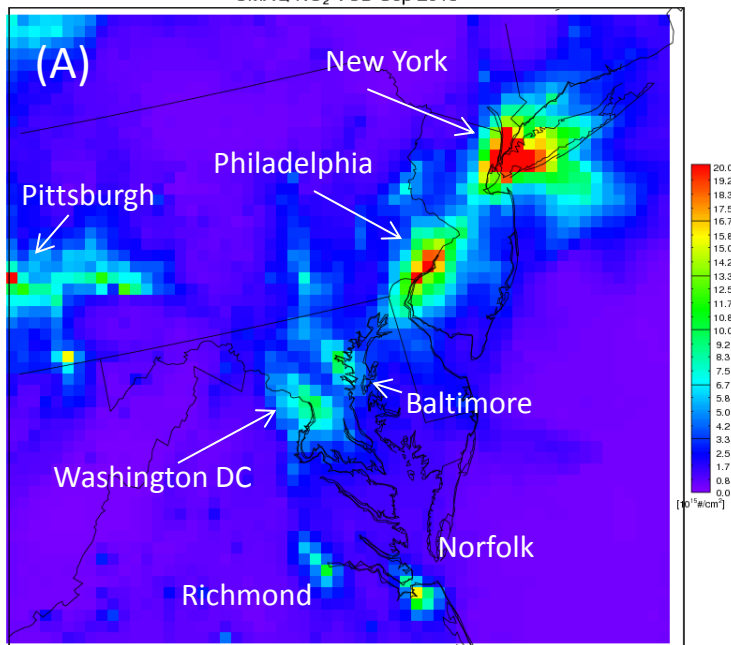
$$P_j = \frac{\sum(p_i \cdot f_{i,j})}{\sum f_{i,j}}$$

where i and j are indices for the model grid cell and OMI pixel, respectively.
 $f_{i,j}$ indicates the fractional area of cell i overlaid by OMI pixel j .



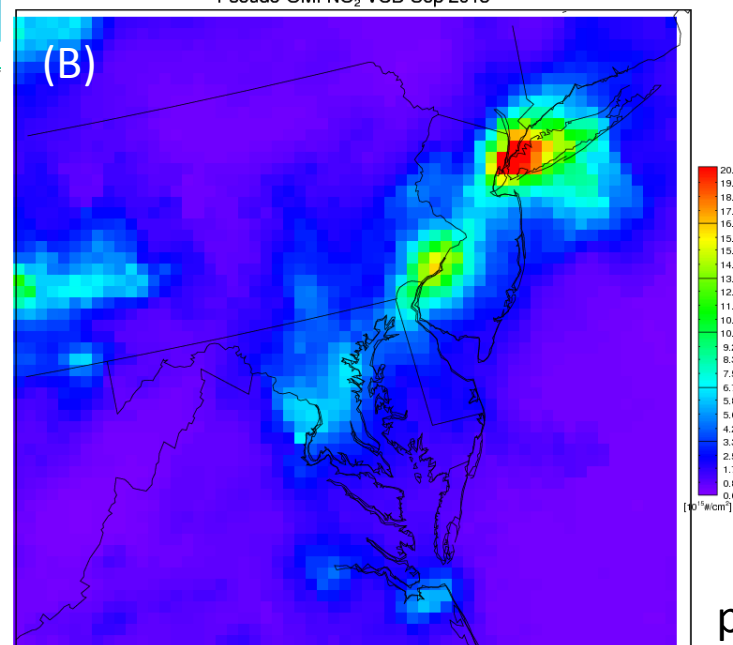
Overlaid fractions using IDL-based geospatial processor (IGDP)

CMAQ NO₂ VCD Sep 2013



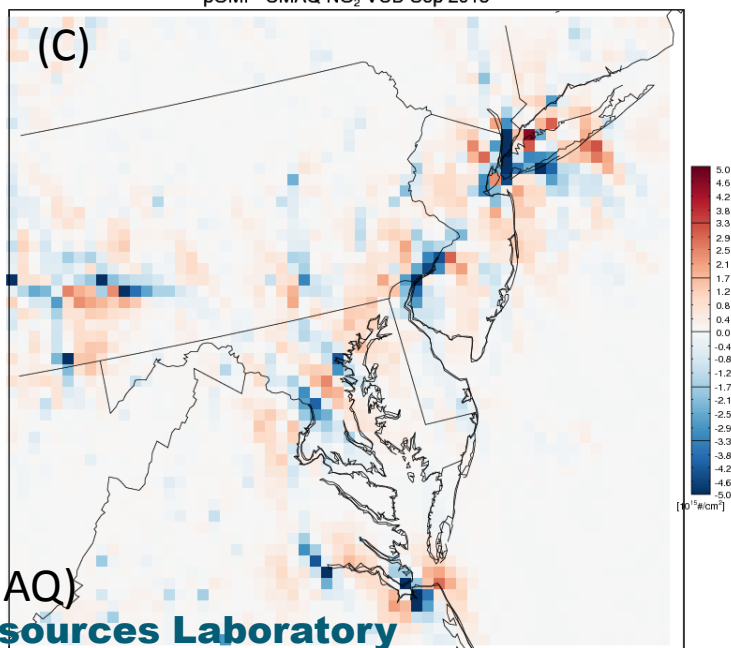
CMAQ

Pseudo-OMI NO₂ VCD Sep 2013

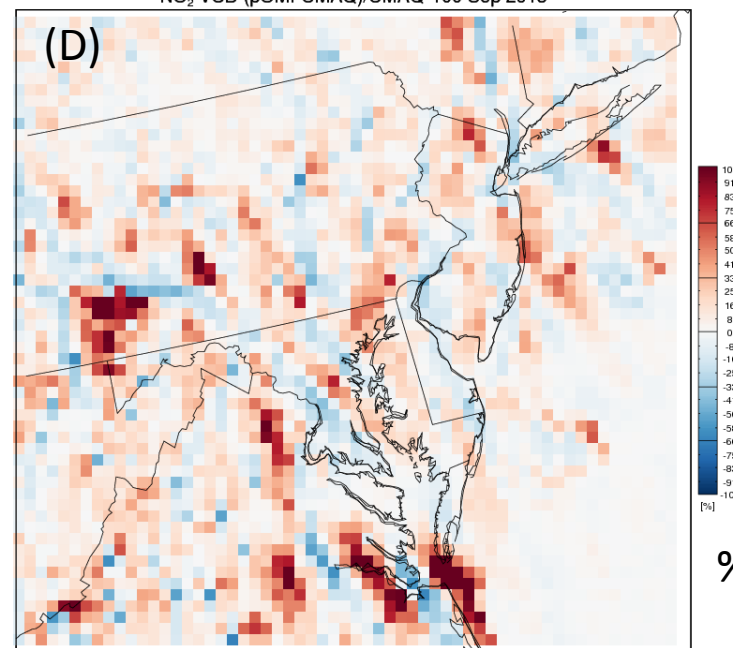


pOMI

pOMI - CMAQ NO₂ VCD Sep 2013



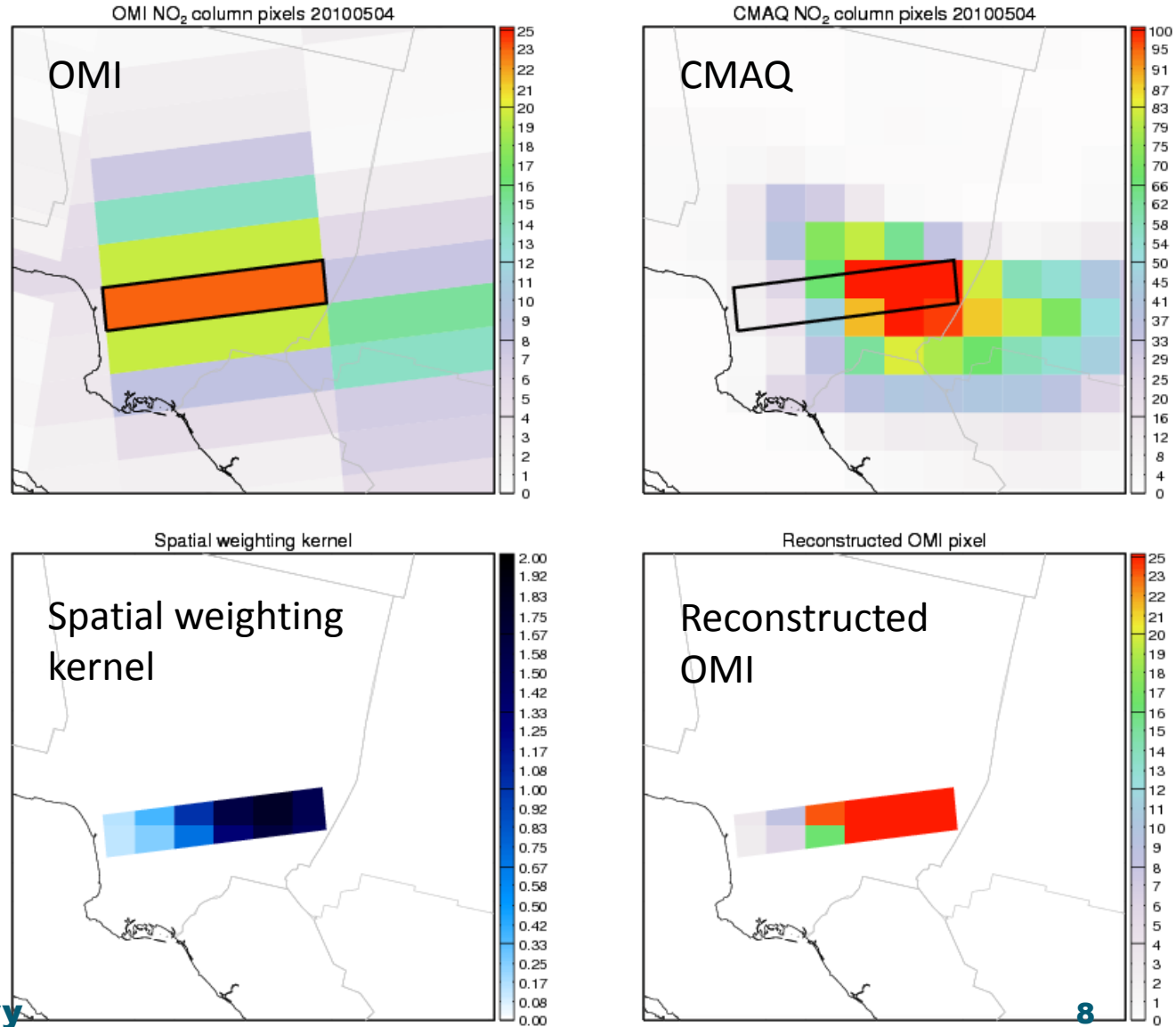
NO₂ VCD (pOMI-CMAQ)/CMAQ*100 Sep 2013



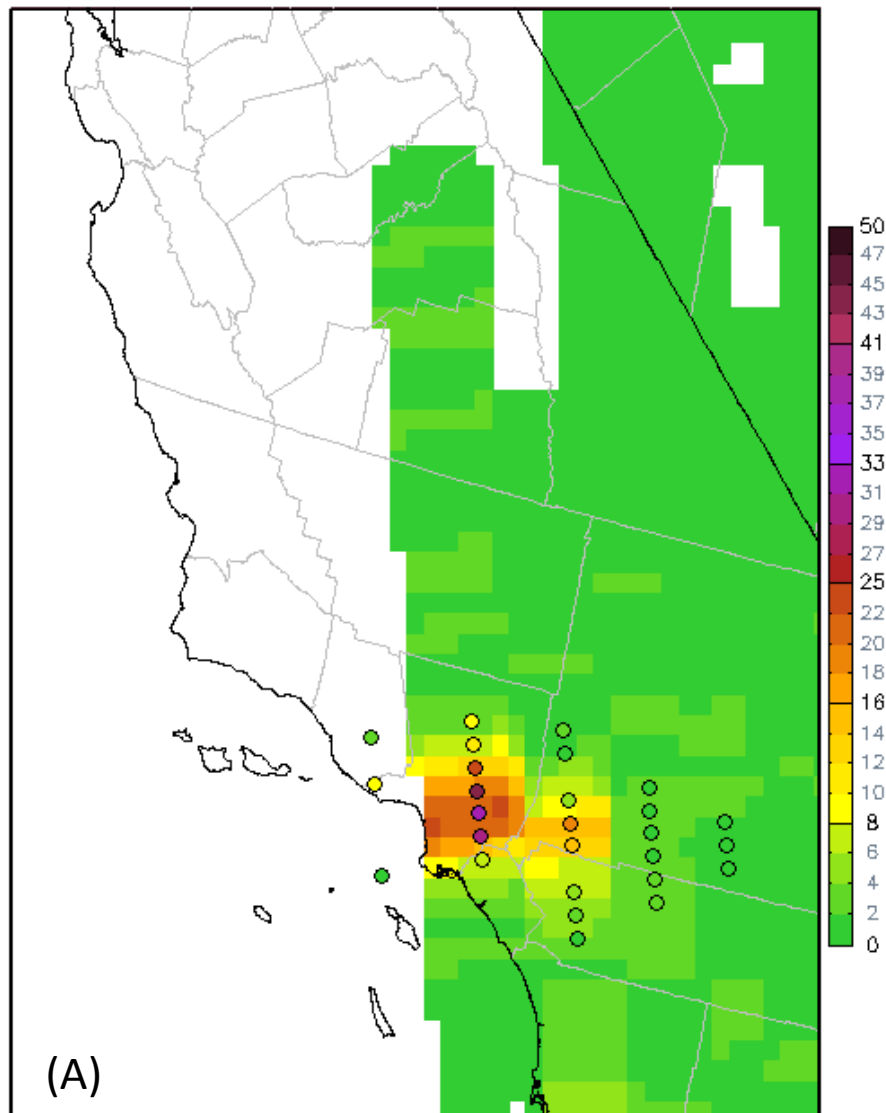
% Diff

Downscaling of OMI

- Apply model's spatial information to OMI pixels
- Model's emission inventory has high uncertainty in its intensity, but has reliable accuracy in the location of emission sources.
- OMI's original quantity is strictly preserved



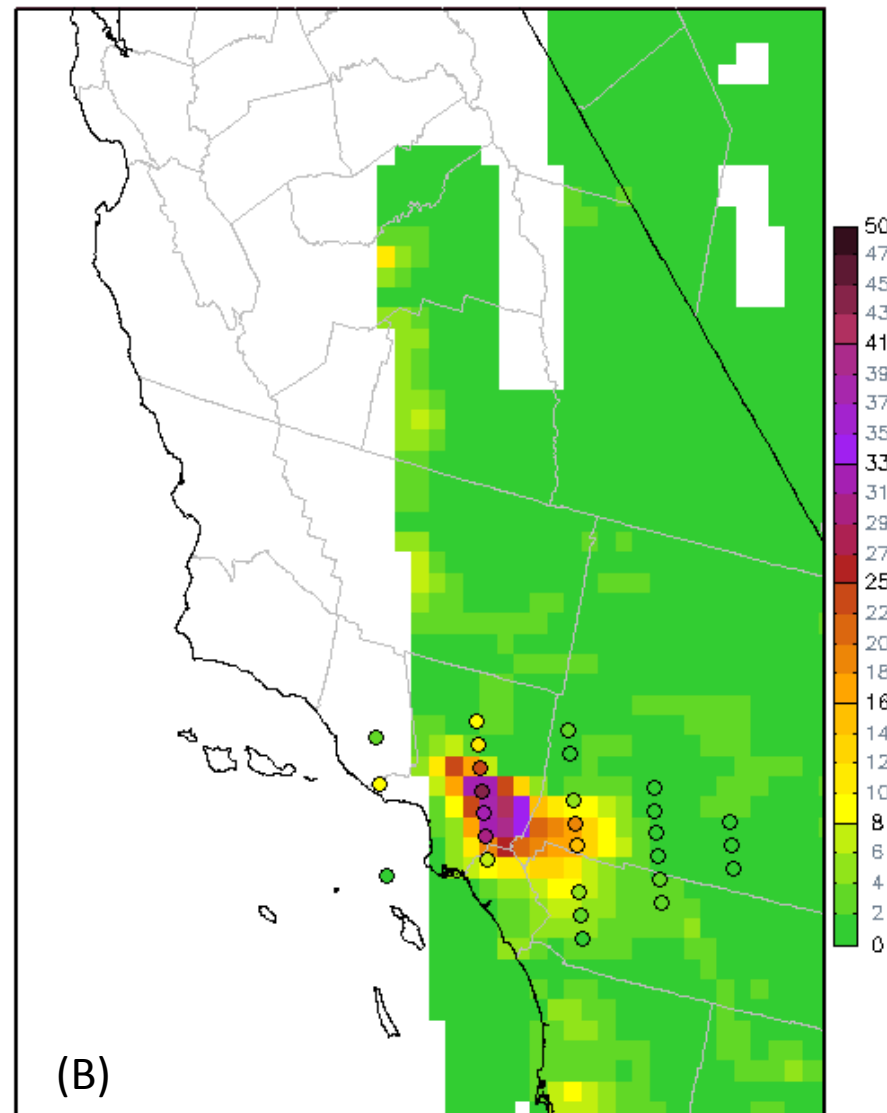
NO₂ VCD (OMI/KNMI) 20100504



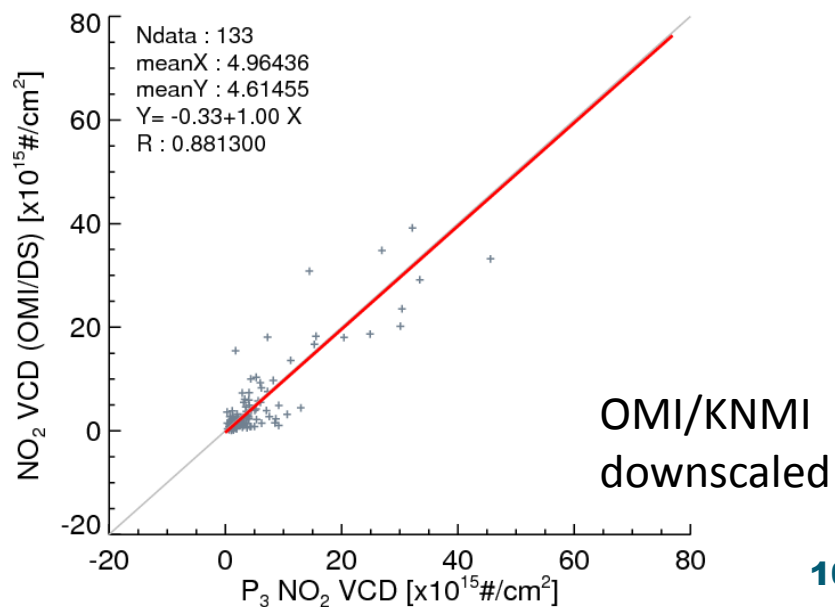
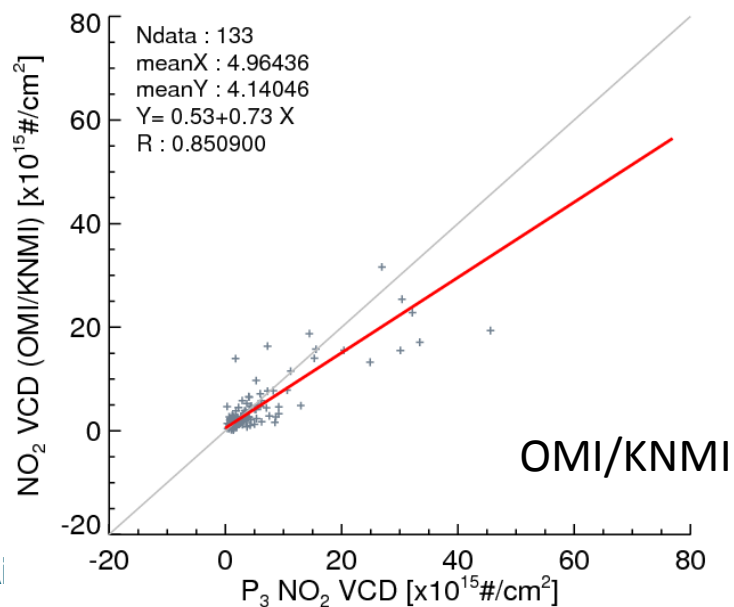
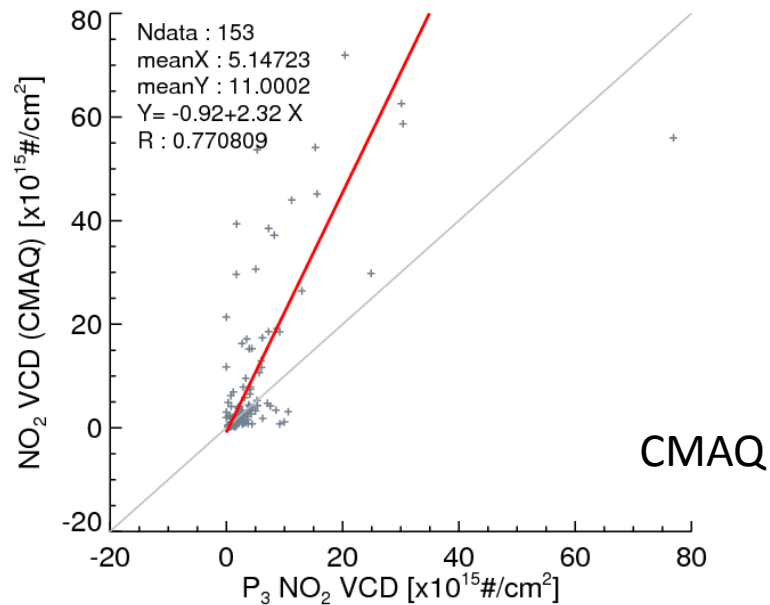
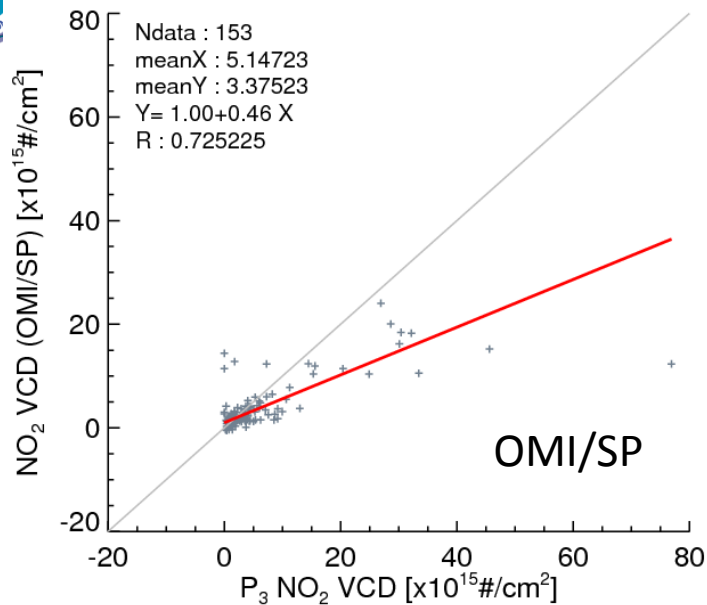
Air Resources Laboratory

[X10¹⁵ #/cm²]

NO₂ VCD (OMI/DS) 20100504



[X10¹⁵ #/cm²]





How downscaling method works

- Satellite measurement is strictly preserved within each footprint. Strength of model does not affect satellite measurement's strength at all.
- The only information that passed from model to satellite is relative spatial information within each satellite footprint.
- Eventually, this method converts systematic negative bias due to coarse resolution to random errors, which can be cancelled out by temporal averaging.



Application to NAQFC

- For “Fair” comparison of satellite & model, we apply two adjustment for vertical and horizontal resolution.
 - Vertical adjustment: Averaging Kernel (AK) is a linear representation of the weighting of information content of retrieval parameters.
 - Spatial adjustment: Conservative downscaling

CMAQ NO₂ VCD / Sep 2013 / xAK

CMAQ NO₂ VCD / Sep 2013 / AK

(A)

(B)

CMAQ

CMAQ with AK

OMI NO₂ VCD / Sep 2013 / xDS

OMI NO₂ VCD / Sep 2013 / DS

(C)

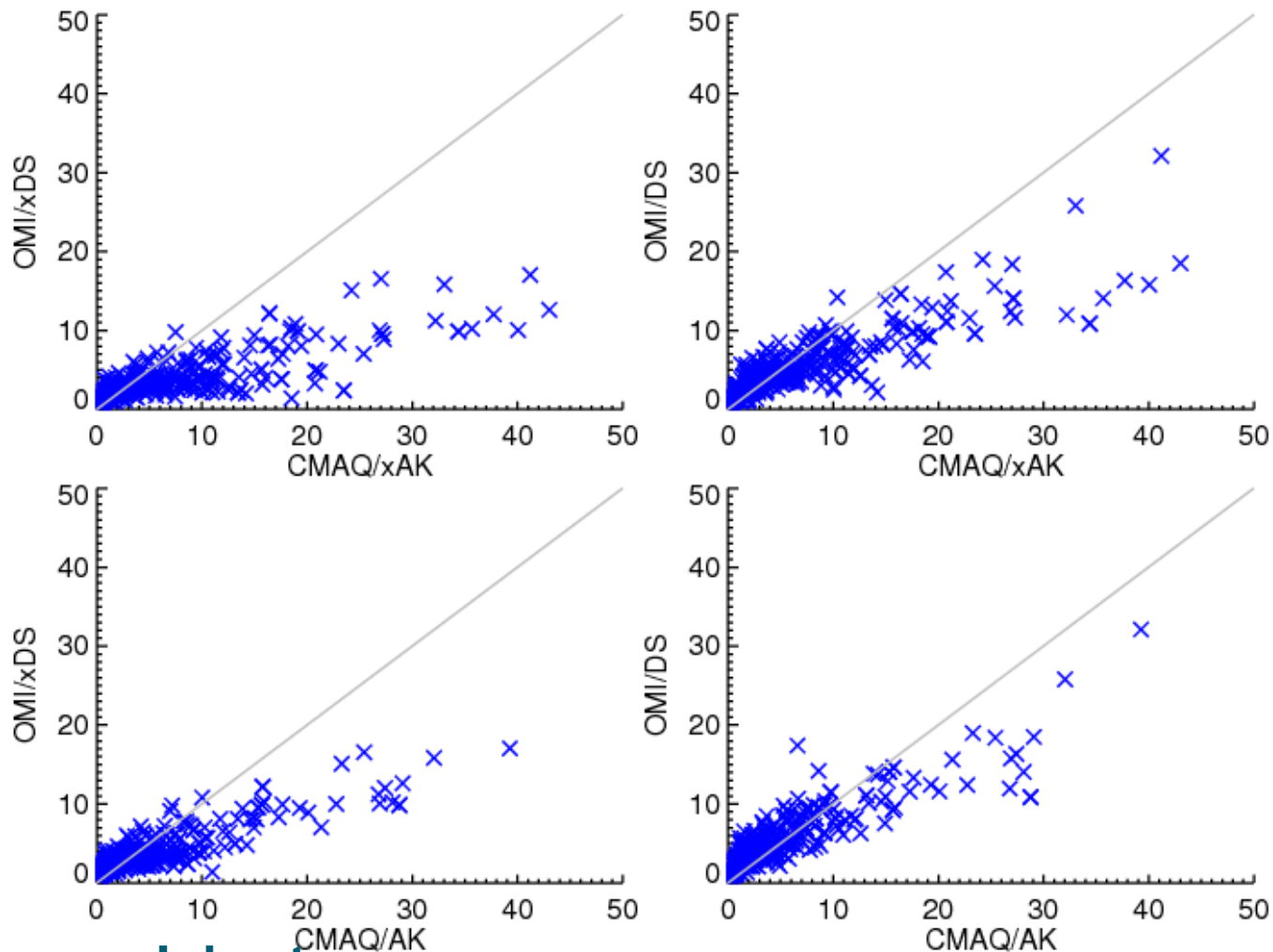
(D)

OMI

OMI with DS

OMI & NAQFC NO₂ VCD comparison: Averaging Kernel(AK) & Downscaling (DS)

NO₂ VCD @ AQS sites / Sep 2013



Overestimation or underestimation?

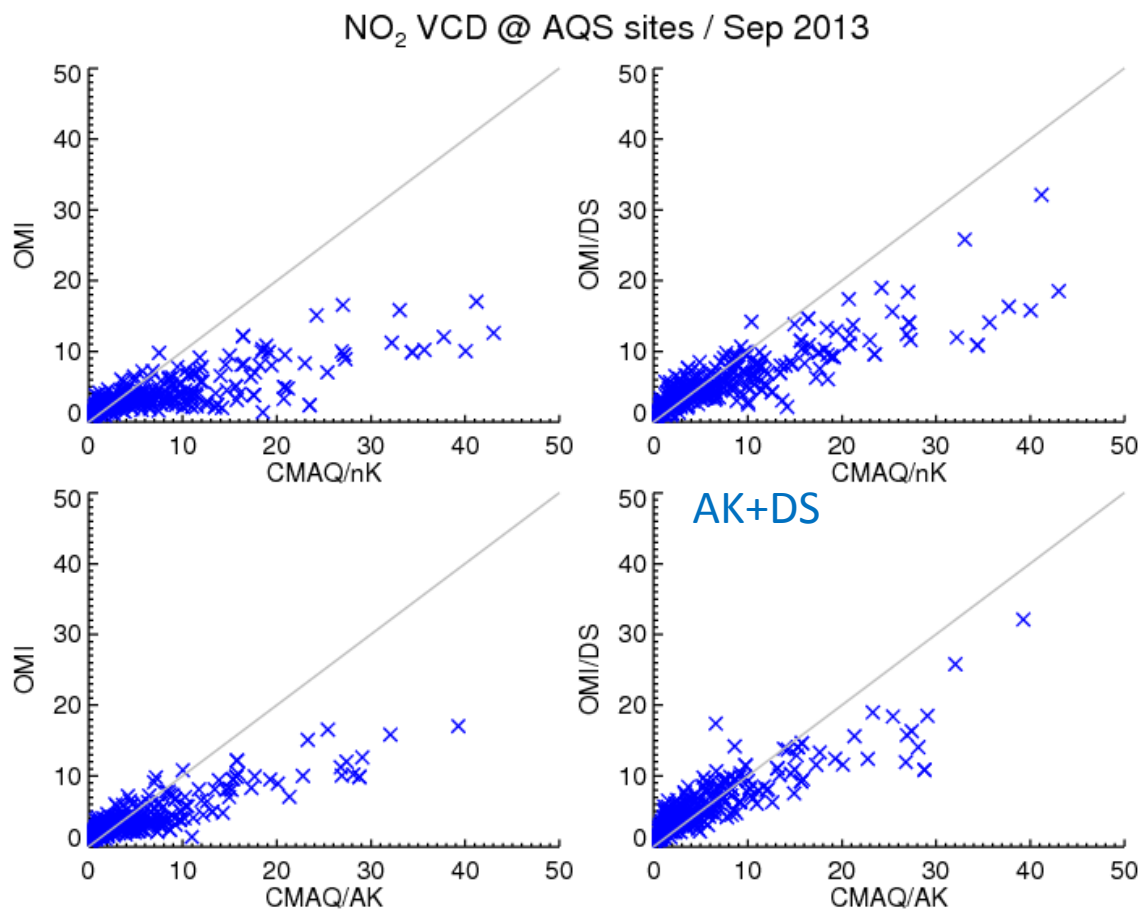
$$\frac{(OMI - CMAQ)}{OMI} \times 100$$

$$= \frac{(6.43 - 3.61)}{3.61} \times 100$$

$$= 78.1\%$$

$$\frac{(4.65 - 3.61)}{3.61} \times 100$$

$$= 28.8\%$$



$$\frac{(6.43 - 5.00)}{5.00} \times 100$$

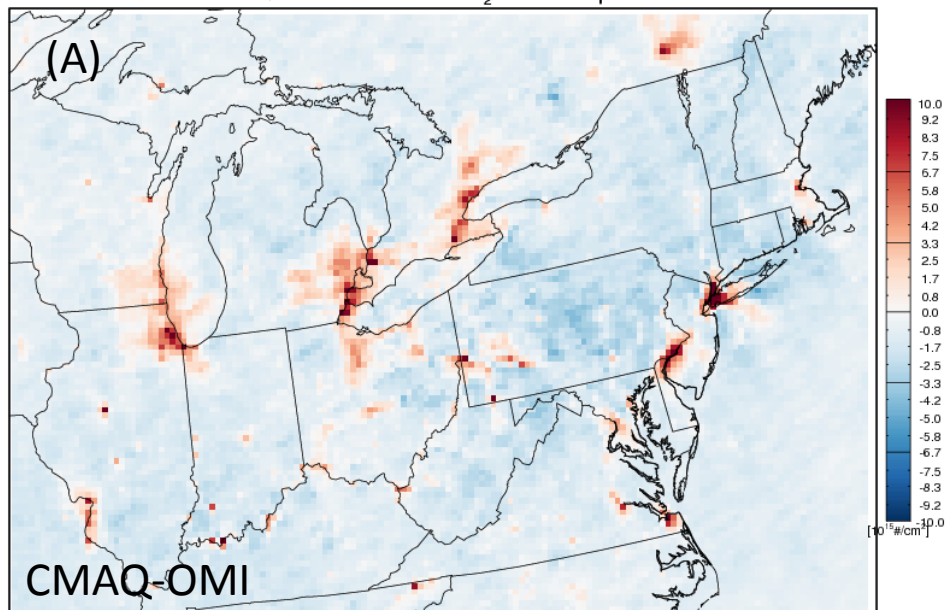
$$= 28.6\%$$

$$\frac{(4.65 - 5.00)}{5.00} \times 100$$

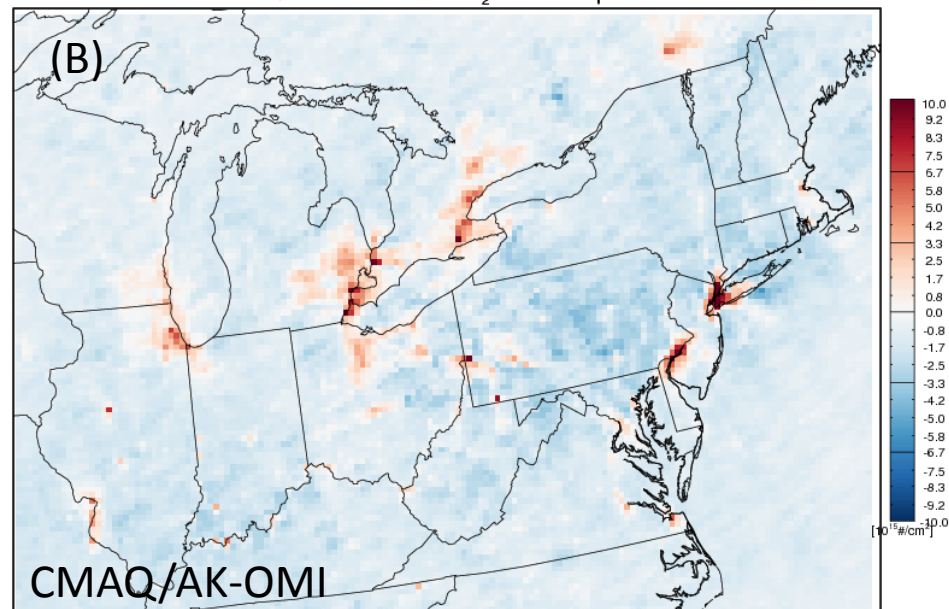
$$= -7\%$$

Underestimation

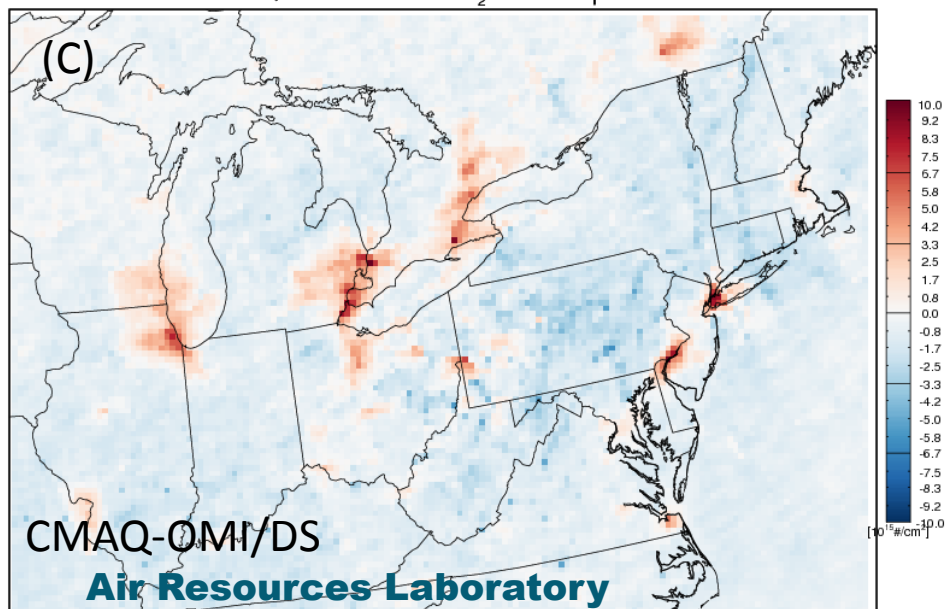
CMAQ/xAK - OMI/xDS NO₂ VCD / Sep 2013 /



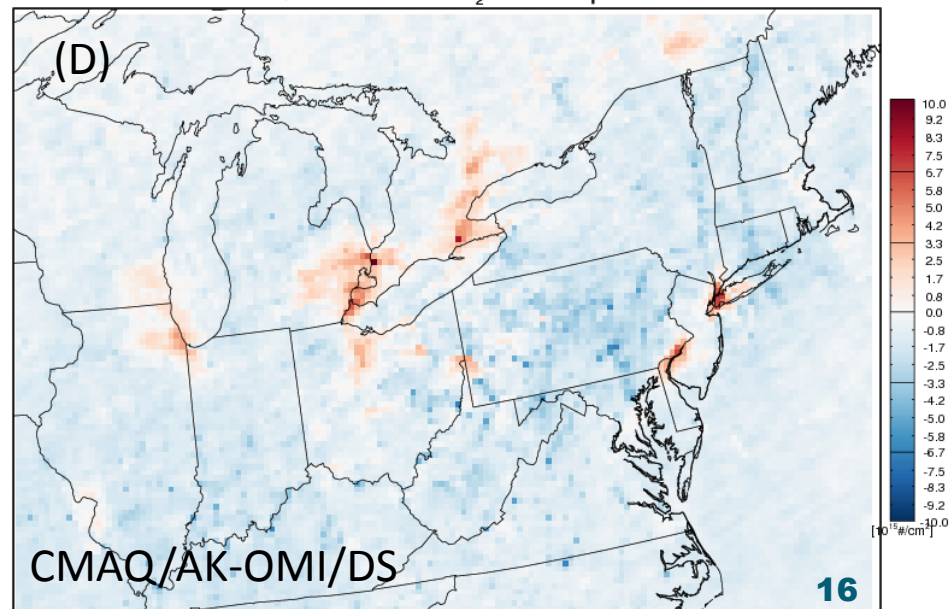
CMAQ/AK - OMI/xDS NO₂ VCD / Sep 2013 /



CMAQ/xAK - OMI/DS NO₂ VCD / Sep 2013 /



CMAQ/AK - OMI/DS NO₂ VCD / Sep 2013 /





Conclusion

- OMI footprint pixels are larger than typical urban NO₂ plume scale, resulting in a considerable underestimation over urban cores.
- Using pseudo OMI data, we estimated that biases are up to 20-30% over mega cities and up to 100% over most cities.
- We introduce a conservative downscaling method to combine OMI observations and CMAQ spatial information. OMI and CMAQ show the best agreement when both *averaging kernel* and *downscaling technique* are applied.
- Satellite and model comparison requires more cautions. Without “fair” comparison, it can easily mislead emission regulation policy-making.